

**Report: Work Completed 2007**

**PRESSURE CORES:  
EFFECTIVE STRESS TESTING  $\sigma'$ -CHAMBER**

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## **Context – State-of-the-Art**

Depressurization and/or heating cause hydrate dissociation, which is accompanied by very large volume expansion. Therefore, the characterization of hydrate-bearing sediments must be conducted either using in situ testing within boreholes or in the laboratory using cores while preserving both temperature and pressure. In situ testing requires cumbersome, slow and costly operations and is hindered by boundary strains, dissociation during coring, and the skin depth of measurements into the formation with respect to the region affected by coring. On the other hand, pressure cores must be recovered, handled and tested without ever leaving PT stability conditions to prevent hydrate dissociation and the massive destructure of the sediment structure.

The specimen in pressure cores cannot be transferred to standard geomechanical chambers without de-pressurization. Therefore, two testing systems have been prototyped:

- Through-wall measurements: X-ray and CT scanning, and a multi sensor core logging that includes P-wave velocity, gamma density, and resistivity (by GeoTek; see also LBNL)
- Instrumented Pressure Testing Chamber: cores are gradually displaced into the chamber and tested without de-pressurizing the specimen (Santamarina and co-workers).

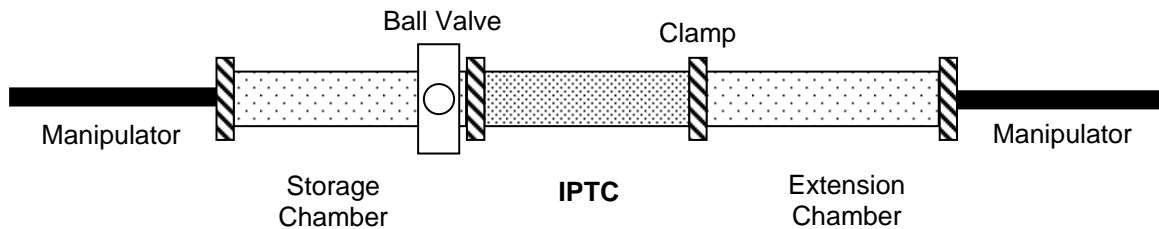
## **Instrumented Pressure Testing Chamber**

The core is stage-tested through ports (see Figure 1): plastic liner drilling, electrical profiling with needle probe, P and S-wave velocity measurement, and undrained strength. The system is very robust and flexible, and it can readily adapted to accommodate the insertion of other measurement and sub-sampling devices. The device has been deployed to characterize sediments in the Gulf of Mexico, India and Korea (Yun et al. 2006, Yun et al. 2010, Lee et al. 2010, and Yun et al., 2011). These studies have provided unprecedented results showing the importance of preventing de-pressurization.

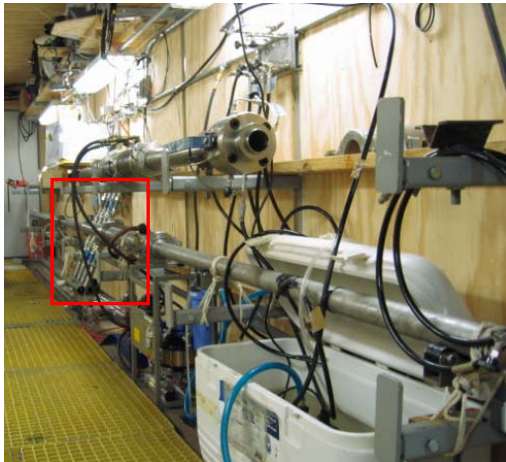
However, the in-situ effective stress is not restored in pressure cores within the Instrumented Pressure Testing Chamber. Yet, the effective stress  $\sigma'$  determines the strength (Mohr-Coulomb), stiffness (Hertz), stress-dependent compaction (Terzaghi), and dilatency (Taylor).

The current pressure chamber testing system:

- The includes the instrumented pressure testing chamber (IPTC), manipulators, storage chamber and extension chamber.
- The overall length is: ~ 35ft (20ft using one-side manipulator, 2005 Singapore).
- Length of s hydrate bearing sediments recovered by pressure coring: ~3ft.
- Properties: elastic wave velocities ( $V_p$  and  $V_s$ ), electrical resistance, shear strength



Deployment



2005 Gulf of Mexico



2006 Singapore  
(samples from Indian Ocean)

Limitation

- Operates within a temperature controlled van.
- Effective stress restoration can not be simulated to study in-situ hydrate bearing sediments.
- IPTC operation requires manipulators and extension chamber

**Figure 1:** GT's Instrumented Pressure Testing Chamber (IPTC) system

## New $\sigma'_v$ -Chamber

We designed and built a new pressure core testing chamber that allows us (1) to re-apply the in situ state of stress on a pressure core (2) that has never been depressurized outside the stability field, and (3) to characterize its properties and monitoring its response using multiple sensing concepts. Schematics and pictures of the built chamber are shown in Figure 2. The new instrument builds on our accumulated knowledge on the design, construction and operation of instrumented pressure chambers.

The system has been designed and built to satisfy the following criteria:

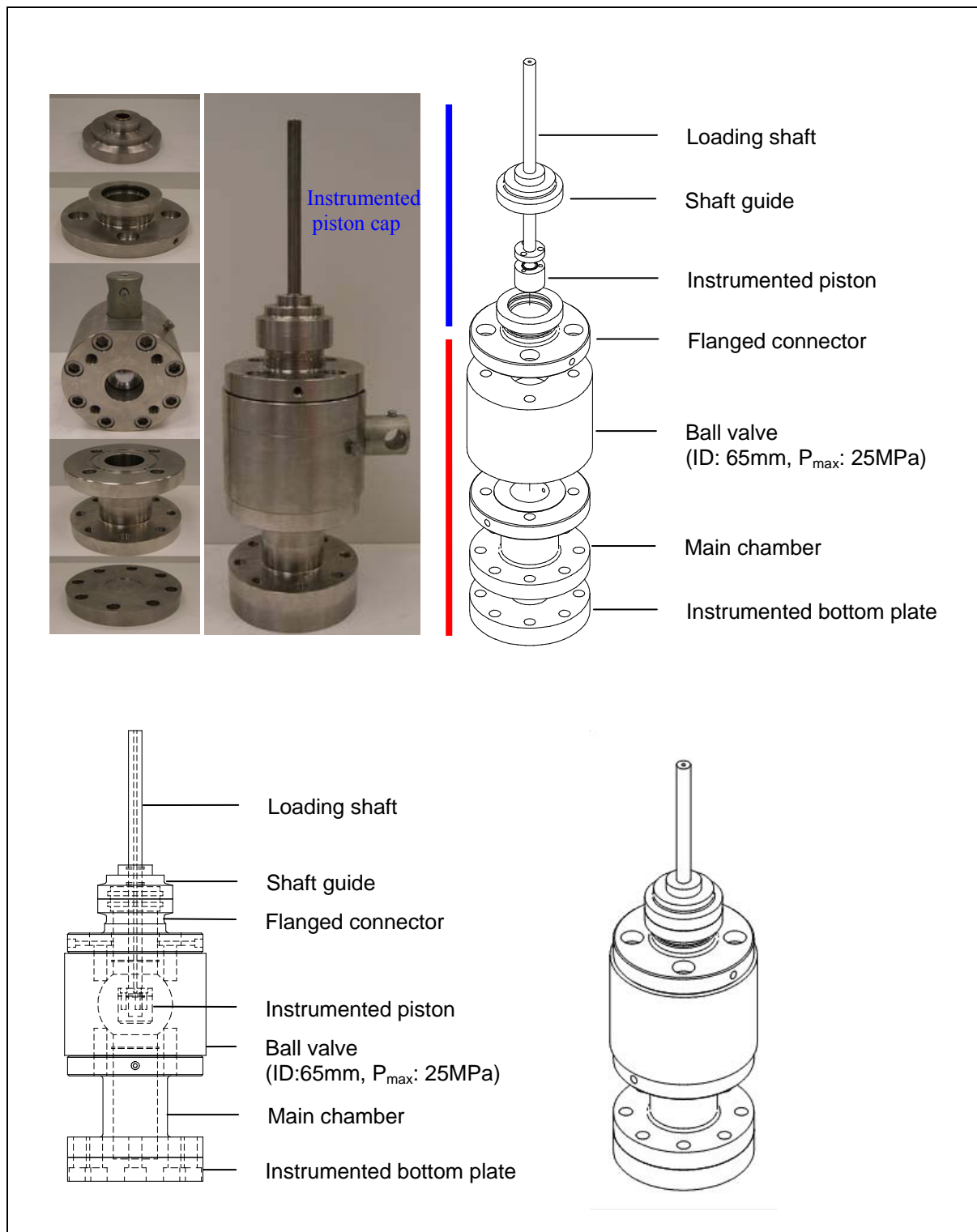
- Robust, reliable operation, adaptable to accommodate wide range of measurement devices
- Maximum pressure: 20MPa. Sample diameter: 57mm
- Input specimen (1) Sample from pressure corers, (2) properly cut 5-to-10cm long specimen within plastic liner, (3) transferred from storage chamber under in-situ fluid pressure
- Instrumentation include: P-wave velocity, S-wave velocity, temperature, undrained shear strength, electrical conductivity, pressure-preserving access ports (e.g., subsampling of either sediment or fluid), hydraulic conductivity.

### Features

- Robust, reliable operation, adaptable to accommodate wide range of measurement devices
- Device height: max 900mm (before loading)
- Maximum pressure: 20MPa (ball valve)
- Instrumented pistons for FPC (57mm ID) and HRC (50mm ID)
- Sample height: ~ 100mm
- Deployment: both in-situ and laboratory
- Properties: P-wave velocity, S-wave velocity, temperature, shear strength, electrical resistance, electrical resistivity tomography (by auxiliary ERT cylinder)

The operation of the chamber involves the following steps (details omitted for simplicity):

- Connect the  $\sigma'_v$ -chamber to the storage chamber where the pressure core with 5~10cm height is stored under in-situ fluid pressure. Equalize pressure. Open ball valve.
- Transfer the specimen to the  $\sigma'_v$ -chamber. Close the ball valve.
- Replace storage chamber with instrumented piston-cap. Equalize pressure. Open ball valve.
- Push instrumented piston-cap against sediment. Restore the in situ vertical effective stress (zero-lateral strain conditions).
- Measure properties



**Figure 2.** New JOI-GT pressure core  $u\sigma'$ -Chamber

The uσ'-chamber can be deployed for in-situ and laboratory applications

- for the comprehensive characterization of hydrate bearing sediments
- for complementary studies such as monitoring the evolution of hydrate bearing sediments during simulated sampling, depressurization, heating,
- for the study of gas production in real sediments
- for the study of coring and sampling effects

Deployment. The chamber (1) has been successfully tested in the laboratory, (2) deployed in the most recent Korean expedition (by KIGAM), and (3) will be extensively used in the next JIP-DOE expedition to the Gulf of Mexico.

## **References**

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